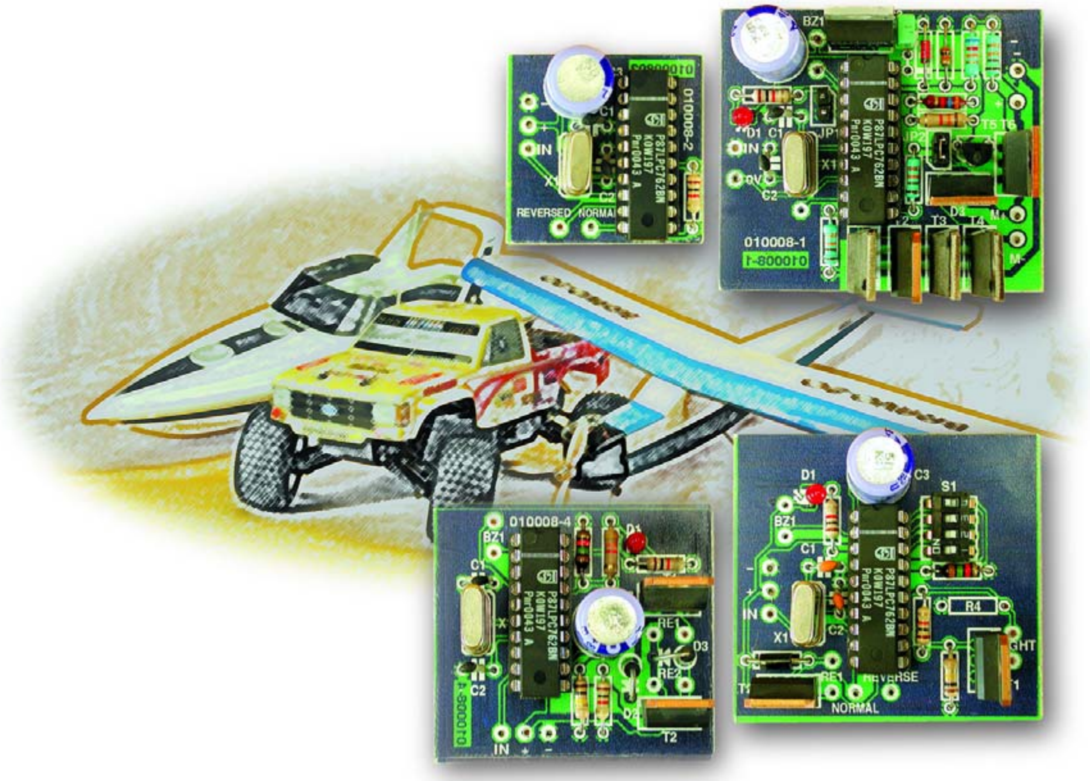
Multi-purpose IC for Modellers (2)

part 2: two printed circuit boards and nine functions

The multi-purpose IC for modellers, offering a total of fourteen different functions, really comes into its own with the two printed circuit boards presented here. This board provides the speed control, soft start, motor voltage monitoring, BEC, anti-collision light, fail-safe, hot glow, servo balancing and go-slow functions.



In the previous article in this series the multi-purpose IC for modellers was presented with two application printed circuit boards. In this second and final instalment we present two further circuit boards. In total these four circuit boards offer fourteen different functions, all using the same IC, a Philips 87LPC762 microcontroller specially programmed for this project. The two new application circuit boards are the 'motor control' and the 'go-slow/hot glow' boards. An overview of the four circuit boards and the functions they offer is given in **Table 1**.

Motor voltage monitoring

In remote-controlled aeroplanes and vehicles, batteries are normally used both for drive and simultaneously, via a BEC system (Battery Eliminator Circuit), to supply the receiver. Since the batteries should not be allowed to discharge too far, and because the BEC requires a certain minimum input voltage, it is sensible to monitor the battery voltage and take suitable action when a critical level is reached.

The system must be designed so that these actions are clear to the user and so that they do not jeopardise subsequent operation of the model. As a permanent optical

Table 1

Printed circuit board and function overview

Printed circuit board 010008-1, 'speed controller', Elektor Electronics, March 2002:
Speed controller, soft start, BEC, model finder, receiver voltage monitor, motor voltage monitor

Printed circuit board 010008-2, 'servo reverse', Elektor Electronics, February 2002:
Servo reverse, Y-cable replacement, fail-safe, servo filter

Printed circuit board 010008-3, "hot glow/go-slow", Elektor Electronics, March 2002:
Servo reverse, Y-cable replacement, fail-safe, servo filter, anti-collision light, go-slow, aileron balancing, hot glow, receiver voltage monitor, model finder

Printed circuit board 010008-4, "2-channel switch", Elektor Electronics, February 2002:
Fail-safe, receiver voltage monitor, model finder, 2-channel switch

indication a LED is connected to port pin P1.6. Taking into consideration that the motor voltage monitor function will only be used in conjunction with the soft-start or speed control functions of the circuit in **Figure 1**, we can also cause the motor to stutter: this will provide a indication clear to any modeller. This state can be permanently switched off by briefly switching the motor off and then back on with a nudge on the control stick. This ensures that a safe landing can be made using full motor power.

The above actions are taken when the microcontroller detects that the voltage is too low ten times in a row, measured at intervals of 20 ms. If the voltage monitoring function is not required, resistor R2 at port pin P0.2 should not be fitted. Zener diode D2 protects the microcontroller input from voltages greater than the power supply voltage. If R2 is not fitted, the zener diode **must** be fitted to the circuit board (**Figure 2**). Note also that the Zener diode must be a 0.25 W type.

The required values for the resistors to obtain a desired threshold voltage U_S can be calculated using the formula for a voltage divider. The internal reference, to which the voltage on port pin P0.2 is compared, is 1.23 V. If, for example, R3 is set at 10 kΩ, we have for R2:

$$R2 = 10\ \mathrm{k\Omega} * (U_S - 1.23\ \mathrm{V}) / 1.23\ \mathrm{V}$$

For example: 8 cells, final voltage 8.8 V:
$R2 = 10\ \mathrm{k\Omega} * (8.8\ \mathrm{V} - 1.23\ \mathrm{V}) / 1.23\ \mathrm{V}$
$R2 = 61.54\ \mathrm{k\Omega}$ (preferred value: 62 kΩ)

BEC system

A BEC (Battery Eliminator Circuit) is a system

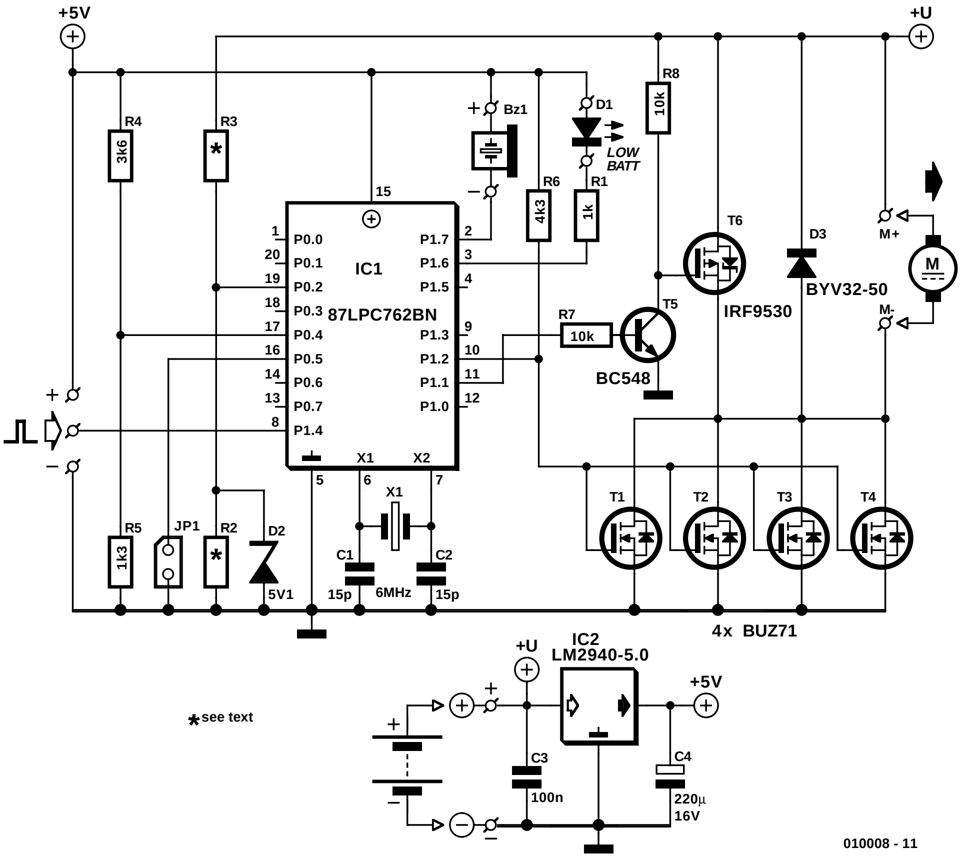


Figure 1. Circuit diagram of the motor control printed circuit board.

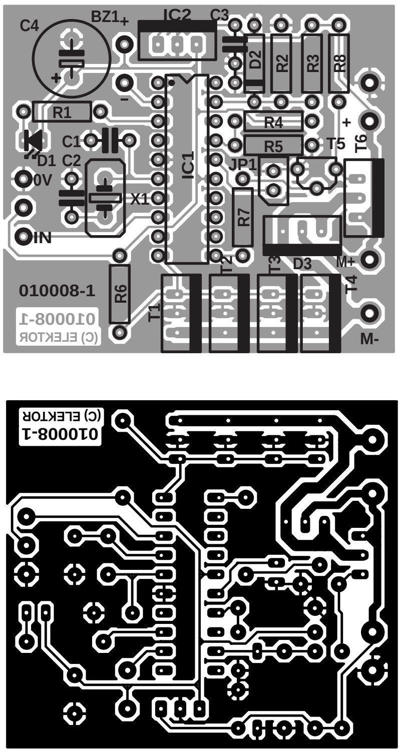
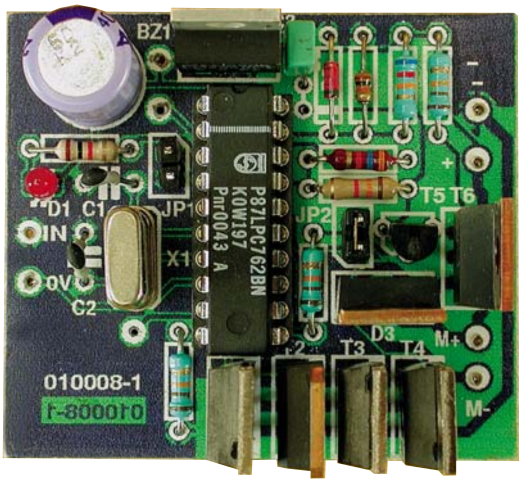


Figure 2. The motor control printed circuit board.



Prototype board (slight differences with final version).

COMPONENTS LIST

PCB 010008-1
(Motor controller, Fig. 2)

Resistors:
R1 = 1kΩ
R2,R3 = see text
R4 = 3kΩ6
R5 = 1kΩ3
R6 = 3kΩ6
R7 = 10kΩ
R8 = 10kΩ

Capacitors:
C1,C2 = 15pF
C3 = 100nF
C4 = 220µF 16V radial

Semiconductors:
D1 = LED, red, low current
D2 = zener diode 5V1
D3 = BYV32-50
IC1 = 87LPC762BN (programmed, order code **010008-41**)*
IC2 = LM2940-5.0
T1-T4 = BUZ71/IRLZ34N
T5 = BC548
T6 = IRF9530

Miscellaneous:
Bz1 = DC buzzer, 5V
X1 = 6MHz quartz crystal
2-way pinheader with jumper
PCB, order code **010008-1***

* For programmed microcontrollers, PCBs and the project software disk, please refer to the Readers Services pages elsewhere in this issue or the publishers' website www.elektor-electronics.co.uk

which replaces the receiver battery with a supply derived from the main battery. The BEC in the circuit of Figure 1 consists of a low-dropout regulator IC2 which can provide a regulated 5 V output for the receiver from a suitable main battery. If this function is not required, IC2 need not be fitted to the printed circuit board (Figure 2) and the power supply for the circuit wired directly to the point marked '+U'.

If IC2 is fitted, there is a power loss which depends on the difference between the main battery voltage and the BEC output voltage, and on the BEC output current:

$$P = (U_{Bat} – U_{BEC})\ I_{BEC}.$$

This power loss is entirely converted into heat. The greater the voltage difference and the greater the current, the greater the power loss and hence the heat produced. This can lead to a significant temperature rise in the IC if no provision is made to dissipate the heat, via a heatsink, for example. A heatsink is recommended for the voltage regulator to dissipate the excess heat if high-power servos are used. In contrast to previous BEC designs employing the 7805 voltage regulator, the low drop-out voltage of the LM2940 regulator used here allows operation down to an input voltage of 6 V. The chief technical characteristics of the LM2940 are as follows:

- 1 V regulator drop-out voltage
- Maximum output current 1 A at T_J=25 °C
- Reverse-polarity protection
- Maximum input voltage 26 V

Speed control

Modern speed controllers for model aircraft are small, light and powerful and driven by a microcontroller. The control algorithm implemented in the multi-purpose IC allows highly efficient speed control of DC motors at currents up to approximately 40 A using pulse width modulation. The motor current is switched by power MOSFETs T1 to T4, which share the load and which switch at a frequency of about 2 kHz. Flywheel diode D3 protects the transistors from voltage spikes as the motor is switched off.

With the motor is turned off the turning of the propeller in the airstream can adversely affect the gliding characteristics of a model. For this reason a braking function is implemented, using T6 to short-circuit the motor. This brake can be disabled by putting the control stick into the fully on position with the transmitter switched on but the receiver switched off, and then turning on the receiver. Helicopter pilots should be aware of this function, which allows the rotor to turn freely. A built-in safety function ensures that the motor does not switch on instantly if the control stick is not initially in the off position: before the motor will start the stick must first be moved to the off position. The range of accepted pulse widths from the receiver is from 1.2 ms to 1.9 ms.

If the battery voltage monitoring function is used and if the voltage goes below the preset minimum value, the motor begins to stutter rhythmically. This stuttering alerts the model's pilot to the low voltage condition. The stuttering can be stopped by briefly switching the motor off and then on again using the control stick.

Since the received pulse width is measured to microsecond accuracy, the resolution of the speed controller and soft start systems is also one microsecond. This gives very fine control, which many other controllers with coarser PWM quantisation cannot match.

Soft start

The soft start switch is constructed in a similar way to the speed controller. The only difference is that that the motor is automatically ramped up to full speed over a period of 2 s. The switching threshold is set when the multi-purpose IC is switched on. The pulse width measured at that point, plus an extra 400 µs (which in practice corresponds to a control stick movement of approximately half its range), sets the value above which the motor will be started. This safety function reliably prevents the motor inadvertently being started up when the transmitter is turned on with the control stick set to its maximum position. The braking function can also be deactivated here in an analogous way to that described above for the speed controller.

Hot glow

When the soft start or speed control functions are activated in the hot glow/go-slow circuit shown in **Figure 3** (with printed circuit board shown in **Figure 4**), port pin P1.0 provides a signal that switches to indicate when the length of the pulse provided by the receive is less than 1.2 ms. The output is switched on when the control setting is in the given range and switched off when the setting leaves that range. An interesting application of this function is the automatic switching of the glow plug supply in four-stroke engines, which idle rather more smoothly with the glow plugs turned on. If the weight of the model is not critical, it is generally worthwhile fitting a battery for the glow plug supply in the model: this avoids fiddling with the glow plug connector, which can be dangerous if it is near a propeller.

MOSFET T2 can easily handle currents up to a maximum of around 10 A.

Anti-collision light

Light effects are eye-catching, and certainly lighting adds interest to a model. The microcontroller's software generates a signal on port pin P0.7 which can be used for an anti-collision light (ACL). The signal drives the lights via power transistor T1, which can comfortably switch currents of 10 A. The flash rate depends upon the pulse repetition rate of the receiver servo signal outputs, and so can vary slightly from manufacturer to manufacturer. At a frequency of 50 Hz, for example, the lights will be switched on for 0.5 s and then off for 1.5 s.

As already discussed, monitoring the receiver supply voltage is very important for the 'survival' of a model. To indicate when the main or auxiliary battery is (nearly) flat, the flash rate of the anti-collision lights is modified in the supply voltage alarm condition, so that the problem can be detected even from a great distance. The flash rate changes to 4 Hz and stays at that value until the microcontroller is reset and the supply voltage restored to a safe level.

Aileron balancing

'Aileron balancing' refers to unequal upwards and downwards deflection of the ailerons. The objective is to compensate for the so-called negative moment (the tendency of the model to fall out of a turn). Models with a large wingspan and symmetrical deflection of the flaps experience different drag on the two wings which tends to yaw the model about the vertical axis against the direction of the turn. This is normally compensated for by an increased rudder deflection, which, however, wastes power. A better approach is to rebal-

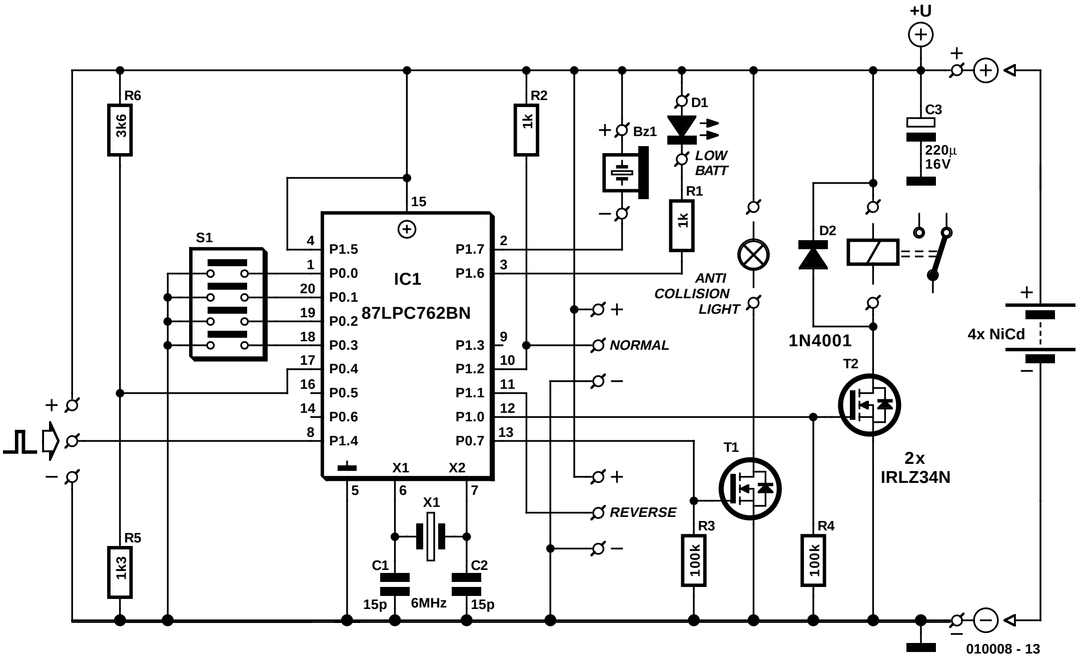
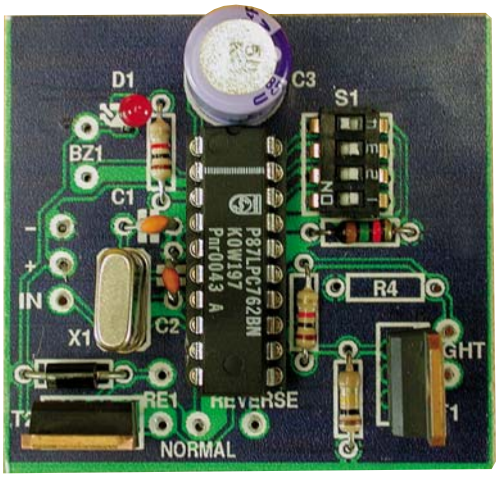


Figure 3. Circuit diagram of the 'hot glow/go-slow' printed circuit board.



Prototype board (slight differences with final version).

ance the ailerons (**Figure 5**), which generally are positioned either 100 % upwards or 50 % to 70 % downwards. These values will vary depending on the geometry of the model.

The degree of balancing effect is configured via DIP switch S1 on the printed circuit board, the three switches S1-1 to S1-3 setting a value in 8 steps (of 10 %) between 20 % and 90 %. The fourth switch S1-4 selects between the aileron balancing function (switch on) and the go-slow function (switch off). **Table 2** shows the relationship between the switch settings and the aileron difference value obtained.

The balancing effect operates only above the neutral position, that is to say when the pulse width of the signal from the receiver lies in the range 1.5 ms to 2 ms. Both servo outputs are affected by this function, the reverse output being affected when the pulse width is in the range 1.5 ms down to 1 ms. This means that two servos operating in opposite directions can be fitted, even though only one receiver output is used.

Go-slow

Modern servos are reliable, powerful and fast. On the one hand, speed can often be very desirable, but on the other hand there are times when the servo cannot be made to move slowly enough. For example, moving the landing flaps suddenly to their end position can give rise to an undesirable consequence such as the model rearing up. Also, a very rapidly moving undercarriage mechanism looks unrealistic. Of course, each servo could be smoothly controlled using a separate controller on the transmitter, but in any case any modeller will be happy to have one fewer control to worry about during landing or take-off. It is important to note that the go-slow

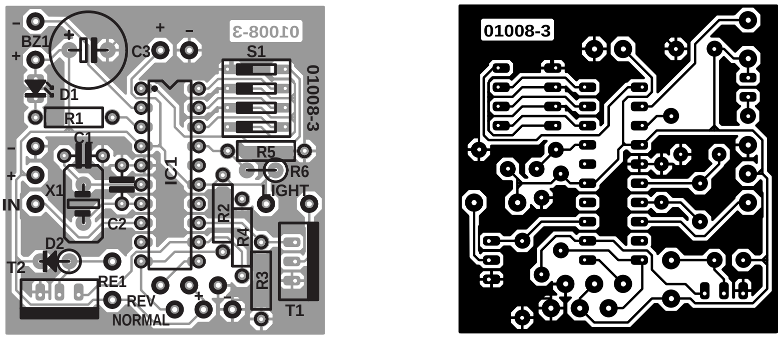


Figure 4. The ‘hot glow/go-slow’ printed circuit board.

COMPONENTS LIST

PCB 010008-3
(hot glow/go-slow, Fig. 4)

Resistors:
R1,R2 = 1kΩ
R3,R4 = 100kΩ
R5 = 1kΩ3
R6 = 3kΩ6

Capacitors:
C1,C2 = 15pF
C3 = 220µF 16V radial

Semiconductors:
D1 = LED, red, low current
D2 = 1N4001
IC1 = 87LPC762BN (order code **010008-41**)*
T1,T2 = BUZ71/IRLZ34N

Miscellaneous:
Bz1 = DC buzzer, 5 V
S1 = 4-way DIP switch
X1 = 6MHz quartz crystal
PCB, order code **010008-3***

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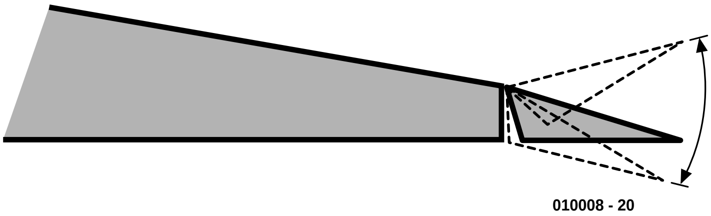

Figure 5. Principle of aileron balancing.

Table 2

Relationship between switch settings and aileron balancing value

Switch settings

1	2	3	4	Difference
on	on	on	on	20%
off	on	on	on	30%
on	off	on	on	40%
off	off	on	on	50%
on	on	off	on	60%
off	on	off	on	70%
on	off	off	on	80%
off	off	off	on	90%
off	off	off	off	0% (‘go slow’ function with zero delay)

Table 3

Relationship between switch settings and delay

Switch settings				delay (s)
1	**2**	**3**	**4**	
on	off	off	off	1
off	on	off	off	2
on	on	off	off	3
off	off	on	off	4
on	off	on	off	5
off	on	on	off	6
on	on	on	off	10
off	off	off	off	zero delay

Note: switch 1 to switch 4 are connected to port pins P0.0 to P0.3
on = switch closed = port pin input sees ground level
off = switch open = port pin pulled up by internal resistor

function does not work with special servos that can only run from one extreme position to the other. These servos cannot be proportionally controlled and therefore also not slowed down.

As far as the servo is concerned the go-slow unit is a black box that sits between the receiver and the servo, measures the incoming pulse, and either increases of decreases the length of the output pulse at a given rate, so that the servo eventually arrives at the position corresponding to the new pulse width at the receiver. The circuit simulates the gradual movement of a control stick at the transmitter, with a speed selectable in seven steps. As well as the applications suggested above, driving the undercarriage mechanism or landing flaps, other possibilities that might lead to interested glances in the direction of your model might include a smoothly-opening cockpit hood or door. The relationship between switch settings and servo speed are given in **Table 3**, where switch S1-4 is responsible for activating the go-slow function (when the switch is in the 'off' position).

The go-slow function also allows two servos to be connected in such a way that they operate in opposite directions but at the same speed. Note that the times given are only indicative values and are dependent on a 25 Hz pulse repetition rate from the receiver. Again, there may be differences here from manufacturer to manufacturer.

Fail-safe

The fail-safe function, which has until now only been available on PCM remote control systems, forces the servos into defined positions in the case of severe interference in the received signal. Whether a model aircraft can carry out a safe landing with the rudder fixed at the mid-position is questionable, but switching off the motor and electrical functions is certainly sensible to minimise the extent of any possible damage. For example, a jammed motor running on the full supply voltage can easily destroy the driver electronics with the excess current. It is also sensible to return the rudder to its mid-position in the case of interference rather than, for example, leaving it at maximum deflection. The fail-safe function is activated when the interference in the received signal is so severe that the microcontroller can no longer decode a valid signal or when the received signal is completely absent (because the model is out of range or because the transmitter has been switched off). The microcontroller then:

1. activates the buzzer;
2. deactivates all switch outputs;
3. in the case of the soft start system and the speed controller, switches off the motor;
4. drives both servo outputs with a pulse width of 1.5 ms.

The fail-safe measures remain in force until a valid received signal is once again available.

MOSFETs

Finally, a few words on the MOSFETs used. Modern examples of this type of transistor feature practically loss-free switching and a low 'on' resistance. It is important to ensure, however, that the gate is always fully driven so that the transistor does not operate in the resistive part of its characteristic. Since only 5 V is available to drive the transistors, so-called 'logic level' types must be used: these allow high currents to be switched without getting unduly hot. The International Rectifier type IRLZ34N suggested is readily available and offers a good price/performance ratio. Its characteristics are as follows:

– I_D: 27 A
– V_{DS}: 55 V
– P_D: 56 W
– R_{DSON}: 0.035 Ω

Modellers who want to squeeze the last drop of performance out of their system might consider using type SUP75N03-04, which, with an R_{DSON} of 0.004 Ω, offer an even lower voltage drop.

(010008-2)

Internet addresses

LM2940:
http://www.national.com/pf/LM/LM2940.html

N-channel MOSFET:
http://www.irf.com/product-info/datasheets/data/irlz34n.pdf

P-channel MOSFET:
http://www.irf.com/product-info/datasheets/data/irf9530.pdf

BYV32-50 :
http://www.mobilesemi.com/us/products/fer.asp

SUP75N03 :
http://www.nessel-elektronik.de/FET_Bauteile/fet_bauteile.html